

1 PREPRINT – VERSION 02/27/2023

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5 **Humans have a basic physical and psychological need to move the body:**  
6 **Physical activity as a primary drive**

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23  
24  
25 Number of words: 10,609

26 Number of Tables and Figures: 2 total; 2 tables, 0 figures

27 Number of Supplements: 0

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29  
30  
31 This article was last modified on February 27, 2023.

32  
33  
34  
35 This work is a preprint (still in peer review), re-submitted to SportRxiv.

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39 Please cite as: Stults-Kolehmainen, MA (2022). Humans have a basic physical and psychological need to move the body:  
40 Physical activity as a primary drive. SportRxiv.

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**ABSTRACT**

Physical activity, while less necessary for survival in modern times, is still essential for thriving in life, and low levels of movement are related to numerous physical and mental health problems. However, we poorly understand why people move on a day-to-day basis and how to promote greater energy expenditure. Recently, there has been a turn to understand automatic processes with close examination of older theories of behavior. This has co-occurred with new developments in the study of non-exercise activity thermogenesis (NEAT). In this narrative review, it is hypothesized that psycho-physiological drive is important to understand movement in general and NEAT, specifically. Drive, in short, is a motivation state, characterized by arousal and felt tension, energizing the organism to acquire a basic need. Movement is a biological necessity, like food, water, and sleep, but varying across the lifespan and having the greatest impact before adolescence. Movement meets various criteria for a primary drive: a) deprivation of it produces feelings of tension, such as an urge or craving, known as affectively-charged motivation states, and particularly the feelings of being antsy, restless, hyper or cooped up, b) provision of the need quickly reduces tension; one can be satiated, and may even over-consume, c) it can be provoked by qualities of the environment, d) it is under homeostatic control, e) there is an appetite (i.e., appetence) for movement but also aversion, and f) it has a developmental time course. Evidence for drive has mainly come from children and populations with hyperkinetic disorders, such as those with anorexia nervosa, restless legs syndrome, and akathisia. It is also stimulated in conditions of deprivation, such as bed rest, quarantine, flights, and physical restraint. It seems to be lacking in the hypokinetic disorders, such as depression and Parkinson's. Thus, drive is associated with displeasure and negative reinforcement, subsuming it within the theory of hedonic drive, but it may fit better within new paradigms, such as the WANT model (Wants and Aversions for Neuromuscular Tasks). Recently developed measurement tools, such as the CRAVE scale, may permit the earnest investigation of movement drive, satiation, and motivation states in humans.

**KEY WORDS**

Drive, motivation, affectively charged motivation states, satiation, exercise, physical activity, non-exercise activity thermogenesis

## 79 INTRODUCTION

80  
81 Movement is important for both physical and mental health, thriving in life and until recently, even survival. While exercise  
82 is widely recognized as improving physical fitness and cardiovascular health (Garber et al., 2011, USDHHS, 2018, Bull et  
83 al., 2020), less recognized is the importance of bodily movement in general, which is necessary for proper circulation,  
84 tissue perfusion (i.e., oxygenation of tissues), metabolism, and many other functions (Greenleaf and Kozlowski, 1982,  
85 DeRoshia and Greenleaf, 1993). Those who move more frequently have less occurrence of blood clots (i.e., pulmonary  
86 embolisms, deep vein thromboses), frozen joints, cartilage degeneration, impaired digestion, metabolic disease and even  
87 skin problems (Pedersen and Saltin, 2015, Musumeci et al., 2013, Crane et al., 2015, Lee et al., 2012, Khmaladze et al.,  
88 2020). Under conditions of movement, weight is maintained in the face of increased or decreased calories (Donnelly et  
89 al., 2009, Levine et al., 1999, Levine et al., 2005). Movement is needed for proper growth, maturation and development  
90 of immune function (Vicente-Rodríguez, 2006). Mental health and even basic perception and psychological attention is  
91 facilitated with movement and degrades with lack of it (Parker et al., 2020, Greenleaf and Kozlowski, 1982, Kim et al.,  
92 2012, Chekroud et al., 2018, Sandler, 2012, de Sousa et al., 2018a, de Sousa et al., 2018b, Zubek, 1964, Pearce et al., 2022).  
93 Even when sleeping, a healthy body continues to move regularly, with about 135 total movements per session of sleep,  
94 of which 15.1 are major postural adjustments (Wilde-Frenz and Schulz, 1983). If indisposed, the body must still be moved  
95 frequently (e.g., by a nurse) to prevent pressure injuries (i.e., skin ulcers), additionally highlighting the importance of  
96 movement (Walton-Geer, 2009). Sudden declines in movement (i.e., outside of normal sleep and rest) are associated with  
97 precipitous worsening of health and accelerated aging (Greenleaf and Kozlowski, 1982, Sandler, 2012). Engagement in a  
98 new and regular exercise routine results in immense health benefits that is dose-dependent, leading some to call it a  
99 “polypill” (Fiuza-Luces et al., 2013). Consequently, one might imagine that movement is as vital as food, water, air, sleep,  
100 shelter, and sexual activity – in other words, a basic or genuine need.

101  
102 Movement falls on a spectrum of energy expenditure and movement intensity, ranging from sleep to vigorous activity  
103 (Biddle, 2022, Rosenberger et al., 2019). Furthermore, movement varies cyclically over a 24-hour activity cycle  
104 (Rosenberger et al., 2019), typically higher when one is awake and peaking in the afternoon (McDonnell et al., 2022).  
105 Energy expenditure, per se, is largely not under volitional control, with the majority of energy being expended  
106 automatically by the resting metabolic rate (RMR) and the thermic effect of food (TEF) (King et al., 2007). Substantial  
107 energy expenditure, however, is under volitional control, such as lifestyle and occupational physical activity and structured  
108 exercise. All physical activity not expended by exercise, RMR or TEF is deemed non-exercise activity thermogenesis (NEAT),  
109 which cannot be directly measured (Levine et al., 1999, Levine et al., 2005). Within NEAT falls incidental or spontaneous  
110 physical activity (SPA), such as fidgeting, pacing, and postural adjustments, may also result in substantial energy burn  
111 (Garland et al., 2011). Some sedentary behavior common for our ancestors and in hunter gatherers of today, such as  
112 “static squatting”, results in enough muscular activity that it could be construed as a form of physical activity. This signifies  
113 the complexity of separating physically active and sedentary behaviors, the latter of which typically includes sitting  
114 (Raichlen et al., 2020, Higgins et al., 2022). For this hypothesis and theory paper, it is important to note that some volitional  
115 activity could also be characterized as “obligatory” (Garland et al., 2011) and instrumental (Stults-Kolehmainen et al.,  
116 2020a) (see below).

117  
118 Unfortunately, with modern times, physical activity and exercise have declined, and sedentarism has become dominant  
119 (Ussery et al., 2021, Hyde et al., 2021). Likewise, calories are abundant along with expanding waistlines and central  
120 adiposity (Wong et al., 2022, Fryar et al., 2021). The putative mechanism is that calories (e.g., particularly from highly  
121 palatable food) are highly reinforcing, while movement is less attractive. Reinforcement, however, has two forms, both  
122 positive (i.e., providing a pleasurable stimulus) and negative (i.e., taking away a negative stimulus). Movement as a positive  
123 reinforcer has been considered extensively (Cheval et al., 2018). Atypically has movement been considered as a negative  
124 reinforcer, such as taking away displeasure (Stults-Kolehmainen et al., 2020a). Drive theory contends that humans are  
125 motivated to extinguish the negative sensations that are usually produced through the deprivation of basic needs (Hull,  
126 1943, Hull, 1952). Bodily movement has periodically been considered as a basic need (Rowland, 2016, Bridges, 1936,  
127 Seward and Seward, 1937). However, while instances of low movement are abundant, it’s uncommon in parlance to think  
128 of oneself as being *deprived* of movement. In fact, some may prefer it that way. Nevertheless, for some, there may be an  
129 obvious need to move, and a sense of deprivation when it is lacking. Furthermore, modern innovations have also produced

situations where humans who are otherwise active become constrained, sometimes for long periods (e.g., academic lectures, flights, space travel, laboratory tasks, quarantine, various forms of confinement and sensory deprivation) (Reardon et al., 2008, Bouwens et al., 2018, Zuckerman et al., 1968, Stults-Kolehmainen et al., 2021a, Blacutt et al., 2021, Filgueiras and Stults-Kolehmainen, 2022, Zubek, 1964, Galton, 1885, Seli et al., 2014, Morgan et al., 2013, Shalev, 2008). If movement is a basic need, there should be a sense of deprivation in these instances. Given these observations, it seems worthwhile to consider whether human movement has drive-like qualities, if it might even be considered a primary drive, and if so, what might be implicated for theories of physical activity behavior. The goal of this hypothesis and theory paper is to explore these issues in both a historical and modern context, drawing on a wide variety of literature. The goal is not to conduct a systematic review, particularly given the difficulties of searching for the term “drive”, and because there is no research question, per se.

## DISCUSSION

### Theories of physical activity behavior

Human movement as a behavior remains an enigma. Dominant theories of exercise and physical activity behavior have largely failed to explain human movement in its totality, largely leaving the concept of daily energy expenditure to the physiologist (Garland et al., 2011). Theories of motivation have typically focused on motives and self-determination, as well other cognitive-oriented constructs (Ekkekakis and Brand, 2021, Ryan and Deci, 2007, Stults-Kolehmainen et al., 2013a, Stults-Kolehmainen et al., 2013b, Biddle, 1995). There has been a recent resurgence of interest in older psychological theories in the construction of dual process theories of motivation (Brand and Ekkekakis, 2018, Conroy and Berry, 2017), which posit both automatic and deliberative components to motivation. For instance, ART theory has resurrected Lewin’s ideas of driving and restraining forces (Brand and Ekkekakis, 2018, Marrow, 1977), yet, attempts to reconcile these inputs on behavior are not unique. Butt (Butt, 1976) commented that, “motivation may be seen as evolving from two major sources: a biologically-based fund of energy, and all secondary or environmental influences, each with positive and negative pulls”. Alderman (Alderman, 1974), took a more comprehensive view, stating, “motivated behavior is the sum total of instincts and needs, motives and drives, conscious and unconscious forces, and a function of what one expects to gain from participation in sport,” which Feige (Feige, 1976) categorized hierarchically to explain physical activity motivation. The ideas of action impulse and urge have also reemerged, though they remain very poorly defined across the literature (Rebar et al., 2018, Stults-Kolehmainen et al., 2020a, Stults-Kolehmainen et al., 2022a, Gardner, 2015, Ekkekakis and Brand, 2021, Brand and Ekkekakis, 2018, Williams, 2023).

With attention now placed on older theories and constructs and rectifying them with newer ones, it begs the question of the relevance of some of the oldest theories of motivation, Drive Theory and the related Drive Reduction Theory (Hull, 1943, Hull, 1952). Drive theory posits that humans are motivated primarily to reduce tension and arousal, typically occurring from the deprivation of basic needs (Allen et al., 2017). With the dawning of behaviorism and cognitivism, this idea has been largely ignored, relegated or simply forgotten (Skinner and Morse, 1958). Early sport and exercise psychologists were disappointed with the ability of Drive Theory to predict the effects of arousal, and in particular anxiety, on performance of complex motor tasks, and they recommended the abandonment of the concept (Landers, 1980, Tenenbaum and Bar-Eli, 1995, Martens, 1971, Martens, 1974). These researchers had little interest in applying the concept to general movement and physical activity behavior. Those that were interested in exercise behavior were turned off by the idea of “people as machines” (Biddle, 1995).

However, the idea has persisted in the work of exercise physiologists within the notion of *biological control* (Rowland, 1998, Rowland, 1999, Rowland, 2016). In the current exercise psychology literature, “drive” is usually used in the context of basic psychological needs, as defined by Self-Determination Theory (Rhodes et al., 2019), nervous system activity (i.e., sympathetic and parasympathetic drive) (Greenwood and Fleshner, 2019), as well as use in expressions of being “driven” (Frijda, 2016, Lichtenstein and Jensen, 2016). In fields outside of exercise science, there has been an earnest re-examination of the concept (Allen et al., 2017) because while drive has been roundly criticized by some scholars no meaningful substitutes have been found (Conrad, 2021). Recently, the WANT model of physical activity and sedentarism posited that the desire for movement behaviors is attributed to a combination of attempts to reduce tension (e.g., from

drive and stress) and maximizing pleasure and enjoyment (i.e., hedonic motivation) (Stults-Kolehmainen et al., 2020a, Stults-Kolehmainen et al., 2022a, Seward, 1956). This idea deserves further delineation, but my basic postulate is that humans have a primary drive to move.

### Drive and Drive Theory

Drive theory is an early theory of motivation. The idea of drive is a “frontier” concept that straddles the physiology and psychology literatures (Conrad, 2021) and varies widely by field of inquiry (Katsafanas, 2018). It is traced back to the work of German physician Johann Friedrich Blumenbach (1752–1840) who used the term *trieb*, meaning force or impulse (Conrad, 2021). Notably for this review, that term derives from an older word, *trieben*, meaning “to herd animals”. Nonetheless, the term is frequently associated with the works of Nietzsche and Freud (Freud, 1964), who were primarily concerned with the drives of sex and aggression. Since this time, however, the concept of drive has been applied more expansively - making a concise definition difficult to find (Bridges, 1936). Some notable definitions follow here.

1. Clark Hull, who is most closely associated with Drive Theory, described drive as “motivation that arises due to a psychological or physiological need” (Hull, 1952).
2. Baumeister and Vohs (Baumeister and Vohs, 2007) describe it as “increased arousal and internal motivation to reach a particular goal”.
3. The American Psychological Association (American Psychological Association, 2022) defines it essentially as a motivation state (Stults-Kolehmainen et al., 2020a), saying drive is “a generalized state of readiness precipitating or motivating an activity or course of action.” They add, “Drive is ... usually created by deprivation of a needed substance (e.g., food), the presence of negative stimuli (e.g., pain, cold), or the occurrence of negative events.”
4. Seward and Seward (Seward and Seward, 1937) defined drive as “an activity of the total organism resulting from a persistent disequilibrium.”
5. Seward described drive as an “excitatory state produced by a homeostatic disturbance” (Seward, 1956).
6. Conrad (Conrad, 2021) notes that “A drive is fundamentally a force, a pressure impelling the organism endogenously.” Speaking from a psychoanalytic viewpoint, Conrad also describes drive as, “bedrock psychical forces that attach to ideational content and are realized in dispositional states that induce affective, and so evaluative, orientations.”
7. Other perspectives come from: a) Carver and White (Carver and White, 1994) in their studies of behavioral activation, which consider drive as more similar to a trait, and label it as “persistent pursuit of desired goals,” b) Lewin considered drive within his notion of “tension systems” (Marrow, 1977).

Consequently, the idea of drive is multifarious and difficult to operationalize. The most common elements from the definitions above are motivation, psychological states, goals, and homeostasis. A similar problem exists with the concept of stress, which conflates the ideas of stressors (i.e., impinging forces) with strain (i.e., the reaction to stress) (Stults-Kolehmainen and Sinha, 2014, Bartholomew et al., 2008, Lutz et al., 2010, Stults-Kolehmainen and Bartholomew, 2012, Stults-Kolehmainen et al., 2014, Stults-Kolehmainen et al., 2016). In this case, drive has been blended indiscriminately with the ideas of: a) needs, b) deprivation of the need (i.e., a stressor), c) felt tension and affective strain (i.e., a response), d) a process of motivation, and e) a motivation state. Given that the difficulties of stress have been met head on, I suggest that the concept of drive may also be pursued more rigorously. Here I define drive as, “a *motivation state* triggered by deprivation of a need or relevant environmental factors and associated with a subjective feeling of tension, functioning to help the organism maintain homeostasis.” [Note that, below, drive is often referred to as a) a tendency to experience motivation states, which energize the organism to action through processes of deprivation, tension, consumption, and satiation or b) as the *totality of these processes*.]

Given this lack of clarity, I find it best to start with the concept of needs and, specifically, primary needs. For Hull (Hull, 1952), a need is a *biological requirement of the organism*, though Taormina & Gao (Taormina and Gao, 2013) more broadly assert that it is “characterized by, and defined as, a lack of something that is essential to an organism’s (a person’s) existence or well-being.” These researchers, who follow the paradigm from Maslow (Maslow, 1943, Maslow, 1987), specifically note that “physiological needs can be operationally defined as the lack of chemicals, nutrients, or internal (e.g., exercise/health) or environmental (e.g., temperatures) conditions necessary for the body to survive, such that the extended absence of these things could lead to psychological stress or physical death” (Taormina and Gao, 2013). The generally accepted primary needs are food, water, oxygen, warmth, shelter, sleep, and sex (Taormina and Gao, 2013). Seward & Seward (Seward and Seward, 1937) also include: activity, exploration (Butler, 1953), attack and self-assertion, escape, and submission. Clearly, there is no universal agreement on the numeration of the primary drives, and later Maslow (Maslow, 1987) urged ending the deliberation over the matter.

Needs are frequently categorized by the type of stimuli that are needed (e.g., water, food, movement). To help avoid circularity, “need” might be viewed as the lack of the necessary stimulus (Taormina and Gao, 2013). Lack of a necessity results in a state of *deprivation* or deficiency – a threat to homeostasis, and thus a stressor. There is an internal stimulus, a signal, as well as arousal associated with the deprivation. For instance, the condition of hunger is a motivation state produced by the deprivation of needed energy. It stimulates the sensation of being hungry, which is a signal to acquire food. Likewise, thirst is a motivation state, a condition, resulting from deficient water intake, associated with the feeling of being thirsty (see Table 1) (Allen et al., 2017). Sensations produced by drive, like being hungry and thirsty, are almost always unpleasant and are considered sources of tension. Drive, however, is not simply the experience of tension. In Hull’s system, drive is the energy or motivational force that powers behavior (Hull, 1943, Hull, 1952). For Lewin (Marrow, 1977), drive was characterized as a “tension system”. It is an uncomfortable motivation state and resulting arousal, both generalized and specific to the need, with the objective to eradicate the deficiency in the need and focusing the attention of the deprived individual on a target. To acquire and consume the needed substance is to sate or satiate the deprived need, which ensures survival. The process is highly automatic and, theoretically, fundamental across all humans, perhaps all mammals, similar to core affect (Barrett et al., 2007).

### Criteria for primary drives

Specific criteria indicating what constitutes a primary drive are difficult to find, with the exception of Bridges (Bridges, 1936), which predates Hull’s classic work (Hull, 1943, Hull, 1952). Based on considerations above, I propose that criteria would include:

1. Universality: The need is innate and common to nearly all humans, and possibly all vertebrates, similar to core affect (Hull, 1952, Spence, 1956, Barrett et al., 2007).
2. Biological requirement for survival: The need is necessary and not acquired or conditioned.
3. Emerges in deprivation: The drive is highly repeatable in response to the recurrence of need deprivation (Allen et al., 2017).
4. Subjective feeling of tension: Deprivation of the need has a psychological consequence. The condition of deprivation is typically unpleasant, like discomfort, which may be strong (e.g., an urge or craving) and may even be the dominant sensation in some situations. The tension is both generalized and specific to the need (e.g., stomach pangs in response to hunger).
5. Physical manifestations and symptoms: There are observable changes in the physical state, such as altered locomotor activity (e.g., the muscles shake in response to being antsy), along with emotional expression (e.g., being flushed).
6. Consumption: Behaviors are observed to consume the need (Allen et al., 2017).
7. Relief: Tension (thus, motivation) rapidly decreases with the provision of the needed stimulus (i.e., a “rapid diminution of motivational stimulus”) (Seward, 1956).
8. Satiation and Over-consumption: A sense of being “full”, a motivational null-point, while having too much results in unpleasant sensations (Allen et al., 2017).

- 282 9. Developmental time course across the lifespan: The drive is exhibited early in infancy (or even before birth), is  
 283 visible throughout infancy and childhood, and changes with aging (Bridges, 1936).
- 284 10. Under homeostatic control: The need has a circadian rhythm, typically. It is reproduced daily and may change  
 285 seasonally (Budnick et al., 2022).
- 286 11. Responsiveness to other internal and external stimuli: Qualities of the internal environment (e.g., the body) and  
 287 the external environment (e.g., either provocative or dull situations) can stimulate it (Seli et al., 2014,  
 288 Loewenstein, 1996).
- 289 12. Approach and avoidance: Include aversions and appetites (e.g., humans crave fresh and avoid salty water; are  
 290 repulsed by rotten food) (Seward and Seward, 1937, Skinner et al., 2009, Stults-Kolehmainen et al., 2020a).  
 291 Qualities of the stimulus matter as they are relevant for survival.
- 292 13. Biological mechanisms: There needs to be evidence of multi-system biological control to constitute a drive,  
 293 including hormones, neuropeptides, brain circuitry, the microbiome, etc. (Dohnalová et al., 2022, Allen et al.,  
 294 2017).  
 295

296 Drives differ from reflexes, instincts, basic psychological needs, impulses, habits, and predispositions (Seward and Seward,  
 297 1937) (though in a circular definition, Szondi described drive as “an instinctual need that has the power of driving the  
 298 behavior of an individual”) (Szondi). Seward and Seward (Seward and Seward, 1937) explain how drives differ from  
 299 reflexes, “which are readily performed, such as blinking, coughing, and withdrawing from easily avoided cutaneous  
 300 stimuli.” While there is some obvious overlap, drives differ from basic psychological needs, such as the basic need to  
 301 belong (Baumeister and Leary, 1995) (Tomova et al., 2020), and competence and autonomy (Ryan and Deci, 2007).  
 302 Instincts differ from drives in that they can be easily externally provoked and do not need any conscious awareness. Conrad  
 303 (Conrad, 2021) defines them as, “innate and unlearned biological processes realized in fixed action patterns that are direct  
 304 expressions of the twin goals of natural selection: survival and reproduction.” A common example is a mother’s instinct  
 305 to protect her young in danger (Bridges, 1936). The stress reactions of fight and flight, now more accurately  
 306 reconceptualized as “freeze, flight, fight, or fright” may be more pertinent (Bracha et al., 2004). The idea of “impulse” is  
 307 similar to drive in that it has been poorly defined, but ostensibly these are separate but potentially related constructs  
 308 (Conrad, 2021, Brand and Ekkekakis, 2018, Gardner, 2015). For instance, both drive and impulse may be related to a third  
 309 construct, urge, which is a feeling of strong desire to approach an object or behavior.  
 310

311 Importantly, drives may or may not have an object or a precise target. “There is no inherent correspondence between a  
 312 drive and its object in the same way that there is between an instinct and its object” (Conrad, 2021). Conrad goes on to  
 313 add, “drives are fundamentally forces and may be ‘continuously flowing’ without any attachment to an object.” On the  
 314 other hand, Conrad also notes that drives may be vector-like, having both force and direction. In line with these notions,  
 315 the drive for movement may be expressed in a multiple of ways, such as a longing for sport, needing to go for a walk or  
 316 wanting to get fit and more muscular (i.e., all having direction/ an object), or a *pressing readiness to fidget and move about*  
 317 *(i.e., not having direction / an object)*.  
 318

### 319 **Movement as a primary drive: Criteria 1-3**

#### 320 Movement is needed for survival

321 My initial arguments that humans have a basic drive to move were published in a former paper (Stults-Kolehmainen et al.,  
 322 2020a) that, while providing a strong rationale, fell short of emphasizing that movement might be characterized as a  
 323 *primary drive*. To do so would be to imply that movement is necessary for survival – that there is a physical need – which  
 324 is nearly universal (criteria 1 and 2, above). The study of drive has frequently been explored in rodent models, where there  
 325 is strong evidence of a basic drive to move (Garland et al., 2011). However, in an early review on the matter, Lore (Lore,  
 326 1968) has argued that there is inconsistent evidence of an innate drive to move in rodents. However, he included studies  
 327 using activity deprivation ranging from 5 hours to 100 days, thus conflating acute and chronic responses.  
 328

329 Thus far in humans, movement has atypically been included in lists of basic physical needs and thus, primary drives, such  
 330 as eating, drink, sex, social interactions, etc. (Hull, 1952, Loewenstein, 1996, Tomova et al., 2020). Nevertheless, Bridges  
 331 (Bridges, 1936), Seward & Seward (Seward and Seward, 1937), and more recently Taormina & Goa (Taormina and Gao,  
 332 2013) have been direct in the assertion that physical activity (and exercise) is a primary need and drive. Others have been

highly suggestive of the point (Rowland, 1998, Rowland, 1999, Rowland, 2016, Collier, 1970, Feige, 1976, Reiss, 2004, Schultheiss and Wirth, 2008, de Geus and de Moor, 2011, Kalupahana et al., 2011, Tolman, 1932), and it has been partly established above. In short, movement is necessary for instrumental reasons, for play (Rowland, 1998, Rowland, 2016), exploration for acquisition of rewards, and experiencing and processing novel environmental stimuli (Parker et al., 2020, Panksepp, 2006, Schultheiss and Wirth, 2008, Panksepp and Biven, 2012, Frijda, 2016, Cabanac, 2006b, Cabanac, 2006a, Butler, 1953). There is also a general need for stimulation (Ekkekakis, 2013), such that individuals will even subject themselves to painful electric shocks when faced with nothing else to occupy their minds (Wilson et al., 2014). Ekkekakis (Ekkekakis, 2013) summarized older arguments that indicated that humans have an “inherent propensity”, “susceptibility” or “drive for activity”.

### Clinical manifestations

A case for “drive for activity” has also been made in certain clinical conditions, such as anorexia nervosa (Casper, 2018, Casper, 2022, Davis and Woodside, 2002, Scheurink et al., 2010). Aversive sensations associated with a lack of movement are also hallmarks of various disorders, such as Restless Leg Syndrome (Garcia-Borreguero et al., 2011, Khan et al., 2017), akathisia (Iqbal et al., 2007), exercise addiction/dependence. (Garland et al., 2011, Ferreira et al., 2006, Hausenblas and Downs, 2002, Stults-Kolehmainen et al., 2022b, Lichtenstein and Jensen, 2016), and hyperactivity (Scheurink et al., 2010, Willerman, 1973). Some of the earliest observations of this go back over 100 years, such as a case of a girl with akathisia who was rarely able to stop moving (James, 1907). With hypokinetic disorders, such as Parkinson’s and depression, there may be a total loss of desire and urge to move, characterized as motor apathy or psychomotor retardation (Stults-Kolehmainen et al., 2022b, Busch et al., 2016, Sinha et al., 2013). Collectively, I have called the disorders characterized as very high or very low in motor urge as Movement Urge Dysfunction Disorders (MUDD), which seem to fall along a movement urge dysfunction spectrum (MUDS) (Stults-Kolehmainen et al., 2022b). This proposition is supported in the Parkinson’s literature and elsewhere as conditions characterized by hypo- and hyper-dopaminergic states in the cortico-striatal circuits (Sinha et al., 2013). Until recently, however, a strong case was not made for the general population of healthy adults (Stults-Kolehmainen et al., 2020a, Stults-Kolehmainen et al., 2021b, Stults-Kolehmainen et al., 2022a). To support the point, one would need to assert that movement is (has been) a common need for all (most) humans and is (has been) needed for survival – not requiring conditioning. Thus, the first two criteria seem to be satisfied.

### Movement deprivation

It appears that the 3rd criterion from the above list (i.e., deprivation) is met as well. Seward and Seward (Seward and Seward, 1937) note that with “prolonged rest, the refreshed organism requires activity to restore equilibrium.” Arousal emerges when movement is deprived, such as prolonged sitting and physical restraint (Reardon et al., 2008, Zuckerman et al., 1968, Bouwens et al., 2018, Ravussin et al., 1986), which is highly repeatable and has been observed in primates (Butler, 1953) and humans (Stults-Kolehmainen et al., 2021b, Stults-Kolehmainen et al., 2022a, Budnick et al., 2022). Under restrained conditions humans feel “intense uneasiness or craving” or “pressing readiness” or tension, perhaps similar to appetite (Ferreira et al., 2006, Loewenstein, 1996); a comparison propelled by Rowland (Rowland, 1998). Almost anyone can identify with the discomfort of sitting for prolonged periods, feelings of being antsy, jittery, squirmy, restless and/or fidgety, and the relief provided by movement (Levine et al., 2005, Seli et al., 2014). They are also observed in various conditions, such as forced bed rest (DeRoshia and Greenleaf, 1993, Ishizaki et al., 2002), loss of playtime/recess (Jarrett et al., 1998), being constrained during an MRI scan or metabolic testing (Ravussin et al., 1986, Heilmaier et al., 2011, Aoyagi et al., 2003), sudden decline in one’s usual exercise routine or mandated detraining (Mondin et al., 1996, Sugawara et al., 2001), quarantine / confinement (Stults-Kolehmainen et al., 2021a, Blacutt et al., 2021, Filgueiras and Stults-Kolehmainen, 2022, Zuckerman et al., 1968, Shalev, 2008), and sensory deprivation (Morgan et al., 2013).

Here are some specific examples:

1. The use of physical restraints in older adults, ostensibly to prevent falls while moving, causes large increases in anxiety and exacerbates agitation (Scherder et al., 2010).
2. Solitary confinement with movement restriction results in dramatic effects to physical and mental health, and, concordantly, international law mandates one hour of exercise time per day (Shalev, 2008). As movement is a basic need, it is also considered a human right.



- 383 3. College-aged male participants who were physically restricted with straps to a form-fitting bed for 8 hours  
 384 had large increases in somatic complaints, feelings of discomfort, and “muscle tightness, sweating, pain  
 385 in joints, urge to urinate and itching” (Zuckerman et al., 1968).
- 386 4. Even in restricted environmental stimulus training (REST – a float tank designed for sensory deprivation),  
 387 which is designed for relaxation, “a tension develops which can be called a ‘stimulus-action’ hunger;  
 388 hidden methods of self-stimulation develop: twitching muscles, ... stroking one finger with another, etc.”  
 389 (Lilly, 2022).
- 390 5. In their studies of daily energy expenditure, Ravussin (Ravussin et al., 1986) and colleagues constrained  
 391 participants to a nondescript metabolic chamber for 24 hours and did not permit them any kind of physical  
 392 exercise, which resulted in increased spontaneous physical activity (SPA). They noted that, “Because the  
 393 subjects were not allowed to carry out physical exercise, such as isometric exercises or calisthenics, it is  
 394 possible that such activity represents an unconscious need to be active.”

#### 395 Activitystat – the physical activity set point

396 Consequently, there may be an energy expenditure set point, under biological control, resulting in drive to move when  
 397 the level of required activity is not met, and lower drive when there is too much or sudden bursts of activity (Rowland,  
 398 1998, Rowland, 2016, Garland et al., 2011). Bennett (Bennett, 1995) wrote of the general idea of biological control of  
 399 movement,  
 400

401 "As with breathing, elimination, and sexual activity, there can be considerable ambiguity about the degree of  
 402 volition in the timing, frequency, and circumstances of any particular act of eating or exercise. In the moment,  
 403 snacking [and movement] may appear to be altogether subject to conscious control; in the aggregate, however,  
 404 such behavior assumes a certain biologic inevitability."  
 405

406 The drive for movement may, alternatively, be a mere consequence of the drive for energy homeostasis, or central nervous  
 407 system stimulation (Rowland, 1998, Wilson et al., 2014). Rowland coined the term “activitystat” in reference to a  
 408 homeostatic center of control that keeps total daily energy expenditure (TDEE) relatively stable. To maintain the set point,  
 409 subtle and perhaps unconscious adjustments may be automatically applied to modulate resting metabolic rate, incidental  
 410 or spontaneous physical activity, as well as voluntary exercise. There is mixed evidence that when exercise suddenly  
 411 increases, NEAT (i.e., kcals of non-exercise activity) may decrease (King et al., 2007, Westerterp, 2018). A recent study  
 412 purporting to test the activitystat model with various training protocols did not find support for the idea (Gomersall et al.,  
 413 2016). However, a test of this model with provision of activity, but not deprivation of activity, is a poor test of the  
 414 framework. There is less direct evidence that sudden declines in activity may result in increases in caloric expenditure, but  
 415 it is possible that this is due to insufficient methods of investigation.  
 416

#### 417 **The subjective feeling of drive (felt tension): Criterion 4**

418 Drives are associated with strong signals and subjective feelings of urge and tension, which change rapidly with  
 419 consumption, satiation, and over-consumption. If humans have a drive to move, what is the proper term for the feeling  
 420 of tension associated with its deprivation? A lack of food results in hunger and feeling hungry; a lack of water, thirst and  
 421 being thirsty, a lack of sleep, fatigue and feeling tired (see Table 1). Historically, a lack of movement was not a problem,  
 422 and thus no strong word is associated with the state of deprivation, at least in English. Older literature has utilized terms,  
 423 such as “necessity of body exercise,” “volitional promptings”, “intense uneasiness”, “craving”, and “pressing readiness”  
 424 (Bain, 1855, Baldwin, 1891, Baldwin, 1894, Shirley, 1929, Hill, 1956, Finger and Mook, 1971). Several candidates might be  
 425 worthy to succinctly describe “feeling deprived of movement”: feeling antsy, fidgety, driven, cooped up, hyper, wired,  
 426 agitated, on edge or edgy, restless, squirmy, jittery, wound up, keyed up, stir crazy, having cabin fever, or other  
 427 overlapping terms also referring to being energized (Emerson, 2020, Stults-Kolehmainen et al., 2022b, Jarrett et al., 1998).  
 428 Just like psychosomatic sensations of fatigue and energy, feelings of restlessness could be construed as being solely  
 429 physical and/or mental (Herring and O'Connor, 2009). Sensations of energy and fatigue are moderately correlated with  
 430 desires and wants to move and rest (Stults-Kolehmainen et al., 2021b). Feeling antsy has connotations of an external  
 431 source of stimulation (i.e., literally “ants in the pants”), and “cooped up” typically refers to conditions of constraint, while  
 432 being “wired” usually refers to consumption of excess caffeine or other external stimuli (Levitt et al., 1993) and “feeling  
 433

hyper” often describes responses to medications (Rabkin et al., 2004, Hauser and Zesiewicz, 1997). Many other terms also exist: drive for activity (Casper, 2018, Casper, 2022), urges, cravings, and appetite (Ferreira et al., 2006). The collection of these has been generally referred to as “affectively-charged motivation states” (ACMS) for physical activity (Stults-Kolehmainen et al., 2020a, Stults-Kolehmainen et al., 2022a). Lastly, it’s important to note that for those with exercise addiction/dependence, abstaining from movement may result in sensations of withdrawal and cravings for exercise (Garland et al., 2011, Hausenblas and Downs, 2002, Lichtenstein and Jensen, 2016). Overall, “urges to move are well-documented in situations where such sensations are bothersome and unproductive” (Stults-Kolehmainen et al., 2022b).

#### Criteria 5-12

For criteria 5-12, I provide brief evidence.

Criteria 5 (Physical manifestations): Studies of participants in situations of deprivation, mentioned above, discuss various physical responses, like spontaneous and nervous fidgeting (Ravussin et al., 1986). In interviews, undergraduate honors students have indicated that they feel mental and physical symptoms, such as being jittery and antsy, with legs stretching out and twitching when deprived of movement (Stults-Kolehmainen et al., 2022a).

Criteria 6 (Consumption): Empirical evidence specifically connecting the constructs of need, deprivation, felt tension, and resulting behavior is lacking. However, motivation states to move (i.e., desire, want, urge, craving), as measured by the CRAVE scale (Stults-Kolehmainen et al., 2021b), were associated with intentions to be active in the following 0-30 and 30-60 minute time frames (Budnick et al., 2022).

Criteria 7 (Relief): With consumption (e.g., moving), there should be reductions in negative affect built up from deprivation. As one example, older adults who were released from restraints and allowed to move and exercise experienced reductions in agitation and arousal (Scherder et al., 2010).

Criteria 8 (Satiating and over-consumption): Excessive movement is associated with fatigue, soreness, pain, and alterations to locomotion, which may be construed as signals of satiation with movement (Stults-Kolehmainen and Bartholomew, 2012, Stults-Kolehmainen et al., 2014, Stults-Kolehmainen et al., 2016) but are not necessary for satiation to manifest. Satiation might be better indicated by alterations to motivation states. With a maximal treadmill test, desires to move dropped 24%, and desires to rest increased 74%, both of which were large effect sizes (Stults-Kolehmainen et al., 2021b). Evidence of satiation also comes from compensation studies, which show that when activity is very high, NEAT decreases (Garland et al., 2011, Westerterp, 2018). The formally constructed notion of exercise satiation is a recent development that has been typically applied to eating disorders (Barker et al., 2022) but likely also applies for healthy populations. My colleagues and I have coined the term “exertiated” to denote when a person feels satisfied and/or satiated with physical activity (see Table 1).

Criteria 9 (Lifespan development): Movement tendencies are observed even in the fetal stage and are considered predictors of infant health (Perry et al., 2022). Movement, muscle tone, and reflexes immediately after birth are likewise important. According to Bridges (Bridges, 1936), the drive to move rhythmically is exhibited in the first month of life, “General exercise and rest are the first noticeable forms of infant behavior,” the purpose being, “sensory exploration and utilization of the environment”. She notes that the “drive for locomotion” (ambulation) is exhibited at 12-24 months, and these drives are related to the need for more advanced exploration and exploitation of the environment. Rowland has commented extensively on drive for movement in children that wanes with adolescence (Rowland, 1998, Rowland, 2016, Rowland, 1999).

Criteria 10 (Homeostatic control): Movement varies systematically over the course of the day, week, and year (Beighle et al., 2008, Budnick et al., 2022). Recent data from adults monitored 6 times a day for 8 days indicates that motivation states to move are like a biorhythm for over 80% of people. In other words, the majority of individuals have a circadian curve for movement drive (Budnick et al., 2022), similar to eating and sleeping. See above for the related idea of “activitystat”.

**Criteria 11 (Responsiveness to internal and external stimuli):** Exogenous factors, such as daylight, caffeine, illicit drugs, prescription medications, and music, highly influence locomotion (Stults-Kolehmainen et al., 2022b, Stults-Kolehmainen et al., 2020a, Tucker and Gilliland, 2007, Levitt et al., 1993, Kaplan et al., 1997, Rabkin et al., 2004, Hauser and Zesiewicz, 1997). Internal stimuli, like joint pain in individuals with low back pain disorders, regularly propels them to fidget and shift their bodies, sometimes multiple times every minute, in order to relieve pressure and avoid discomfort (Dunk and Callaghan, 2010, Beitel et al., 2016). Psychological stress results in displacement behaviors, such as pacing and stroking one's hair (Troisi, 2002, Mohiyeddini et al., 2013). A lack of stimulation or monotony may also result in activation of drive (Seli et al., 2014).

**Criteria 12 (Approach and avoidance):** Humans have an innate desire to move, particularly in youth, but they also have strong aversions for movement. For instance, when in the thralls of physical pain (e.g., in this case, before movement even starts) most people actively avoid movement – the extreme of which is kinesiophobia (Stults-Kolehmainen et al., 2020a, Glaviano et al., 2019, Beitel et al., 2016, Lundberg et al., 2006). Also, physical labor and exercise in vigorous intensities are sources of punishing sensations, which are in themselves drive to stop moving. However, physical work and its sensations can be conditioned to have less impact. Brown (Brown, 1955) attempted to explain the interactions between drive (in this case, drive to stop moving and rest) and conditioning (e.g., to move more).

“Under some conditions, it might be predicted that the intense [and painful] proprioceptive stimulation and [fatiguing] muscular strain due to prolonged work should have drive-like effects [to stop and/or avoid movement]. But if an organism gets appropriately reinforced training, it can acquire a tolerance for the stimulative effects of repetitive muscular effort that is little short of astounding. Rats and pigeons can be trained to make hundreds of responses for a single bite of food if the percentage of reinforcement is high initially, and if the reduction in frequency of reinforcement with further trials is sufficiently gradual. In such instances, apparently, the stimulation accruing from a multitude of successive reactions does not function as a drive [to stop movement], since behavior, such as resting, though followed by the cessation of such [painful] stimulation, is not strengthened.”

Robinson and Berridge (Robinson and Berridge, 2013) have demonstrated how aversive and punishing sensations can be transformed quickly into strongly desired stimuli via the activation of mesocorticolimbic circuitry, which ostensibly applies to physical activity as well.

### **Movement as a secondary drive**

Primary needs and drives are distinguished from secondary needs and drives, the latter of which are not directly needed for survival but help to optimize survival. Secondary needs have also been referred to as “quasi-needs” (Marrow, 1977). Hull asserted that some reinforcing behaviors, like seeking money, are secondary drives (Hull, 1952). According to Baumeister and Vohs (Baumeister and Vohs, 2007), “Secondary or acquired drives are those that are culturally determined or learned, such as the drive to obtain money, intimacy, or social approval.” Bridges (Bridges, 1936) adds, “Any acquired habit is a drive to some extent”, which is influenced by development; “The primary drives become further differentiated and directed towards varying specific ends with increasing age.” It seems likely that some movement behaviors (e.g., structured exercise) fall within this category. It should be noted that in previous manuscripts, I have indicated that wants and desires for movement may be primary (i.e., want for movement itself) versus secondary (e.g., want to move in order to achieve something else) (Stults-Kolehmainen et al., 2022b). For instance, one may feel antsy and want to move (i.e., a primary want or desire), or one may want a drink of water and thus feel urged to get up and go the kitchen (i.e., a secondary want or desire).

### **The influence of drive on behavior**

How does drive influence behavior? Nietzsche provided one way of describing how drives impact action, which is concordant with the notion of incentive salience (Salamone and Correa, 2002, Berridge and Robinson, 1998). As described by Conrad (Conrad, 2021),

“The drives (1) identify features of the world as salient, (2) induce an affective response to that object [e.g., an urge or craving] that (3) justify a certain evaluation of the world consonant with that affective response, and (4)

impel one toward a certain (set of) behavior(s). Put more parsimoniously, the drives are dispositional states that induce evaluative orientations.”

### Hull's Formula

Hull (Hull, 1943, Hull, 1952) was interested in creating precise formulas to predict behavior from drive, predicated on the idea of stimulus-response. In this case, the response was the “excitation potential” ( $sE_R$ ) - the likelihood that stimulus (s) would result in response (r). His basic formula included: 1) drive strength (D), which was essentially the time of deprivation, and 2) habit strength ( $sH_R$ ), conditioned from repeated reinforcing trials (Martens, 1971). Later, other factors in his formulas included: 3) intensity of the stimulus triggering the behavior (V), such as light or a bolus of carbohydrate, and 4) incentive (the potential pleasure that the stimulus can provide) (K). Further developing more complex models, Hull added: 5) any delay to acquire the stimulus, 6) reactive inhibition or satiation resulting from continued exposure to the stimulus, 7) conditioned inhibition that does not dissipate over time, and other factors, such as the “reaction threshold”. Importantly, *the strongest responses are for stimuli that reduce tension (i.e., negative reinforcement) while also enhancing pleasure (i.e., positive reinforcement)* (Seward, 1956, Allen et al., 2017).

How this might apply to movement could be demonstrated in the following example. A child constrained to a desk will be conditioned to sitting ( $sH_R$ ) as part of adapting to schoolwork but will also freely engage in movement during recess. A lack of movement over the course of morning studies results in drive (D) – a motivation state. Approaching the hour of recess is a stimulus that will activate an anticipatory response (V), and the incentive of playing a fun game provides a powerful forecasted reward (K). Moreover, any delay in recess beyond the normal time will result in growing arousal and discomfort (i.e., tension). “Drive” here may be observed with physical manifestations of tension, such as fidgeting, pacing, swaying, shifting of the body, sweating, etc. This affect may be modulated, however, by additional training to sit still. The eventual engagement in play will, more than likely, swiftly result in reduced tension, as predicted by Hull (Hull, 1952).

### Drive Reduction Theory

Hull's drive theory was not just a theory of how the organism responds to deprivation of needs (Hull, 1952). His Drive Reduction Theory was a paradigm of motivation, learning, and the development of habits. The organism is motivated to eliminate aversive feelings, which he later called cravings, and will behave to do so (Hilgard and Bower, 1975). In the case of hunger, it will feel peckish and will search for food (via movement) to reduce those pangs. Inevitably, the deprivation occurs again, and the organism repeats the behavior that previously reduced the drive, developing a habit. Importantly, reducing a sensation of drive was the principal reinforcement for human behavior (and not merely the attainment of pleasure, for instance).

Several criticisms of Drive Reduction Theory led to its relegation.

1. It is highly formulaic and unwieldy, and experimentation from Skinner provided cleaner experimental design (Smith, 2000, Skinner and Morse, 1958).
2. Not all human behavior has the goal of reducing tension. Clearly, humans are highly driven to attain pleasure (Young, 1966) and not just reduce arousal.
3. On the other hand, it is easy to observe contra-hedonic processes, in other words, pain seeking (Riediger et al., 2009).
4. Drive Reduction Theory was principally sidelined, however, because of observations that consumption of wanted and needed stimuli did not always result in reductions in drive and arousal.

To follow this last point, sometimes, there is increased arousal with consumption. A famous example is a person who leaves the comfort of sitting to ride a roller coaster – the sensation seeker looking for more tension (i.e., arousal) – not less (Brown, 1955). In the school recess example above, Hull's theory, as modified by Brown (Brown, 1955), predicts that the play will result in increased arousal. Since this time, sensation seeking has been well accepted (Babbitt et al., 1990a, Babbitt et al., 1990b, Rhodes and Smith, 2006). More recently, the idea that “some like it vigorous” (Ekkekakis et al., 2005); in other words, some people prefer vigorous levels of activity and can readily tolerate high intensities. Importantly,

586 it appears that Hull conflated the concepts of displeasure with arousal in his ideas about tension. In these examples, there  
 587 will be strong reduction in negative affect (i.e., reduced sense of displeasure) and enhanced positive affect, as commonly  
 588 observed in studies of exercise (Jones and Zenko, 2021). Consequently, Drive Reduction Theory has faded; nevertheless,  
 589 the idea of drive has persisted because it aligns with observed data (Allen et al., 2017).

### 591 **Affectively-charged motivation states and the WANT Model**

592 Can Drive Reduction Theory be rehabilitated and melded with the widely accepted Hedonic Theory? In his thorough  
 593 critique of both theories, Seward (Seward, 1956) acknowledged that, “Since the two theories are not strictly incompatible,  
 594 it is possible to accept both. Indeed, the foregoing evidence strongly indicates that both drive reduction and incentive play  
 595 a part in reinforcement.” Recent work has attempted to combine classic work on aspects of drive theory with hedonic  
 596 theory and other recent theories of physical activity (Brand and Ekkekakis, 2018, Stults-Kolehmainen et al., 2020a). I  
 597 highlight the Wants and Aversions for Neuromuscular Tasks (WANT) model, which has been discussed extensively  
 598 elsewhere (Stults-Kolehmainen et al., 2020b, Stults-Kolehmainen et al., 2020a, Stults-Kolehmainen et al., 2021b, Stults-  
 599 Kolehmainen et al., 2022b, Stults-Kolehmainen et al., 2022a, Budnick et al., 2022, Filgueiras et al., 2022). In the WANT  
 600 model, humans are motivated to reduce tension (as in Drive Reduction Theory) and to approach pleasure (as in Hedonic  
 601 Theory) (Young, 1966). Moreover, this model emphasizes the subjective feelings of wanting or desiring to move, which  
 602 are called affectively-charged motivation states (ACMS). ACMS to move may be felt weakly, such as a want, or strongly,  
 603 such as an urge or craving. Importantly though, while drive sensations (e.g., tense arousal), which are considered  
 604 motivation states, are typically considered unpleasant, sensations of wanting to move may be experienced as pleasant.  
 605 This is well documented, for instance, in the concepts of groove and swing (Stults-Kolehmainen et al., 2022b, Janata et al.,  
 606 2012, Janata et al., 2018), which are the ability of music to stimulate pleasurable desires to move the body. Thus, ACMS  
 607 and the WANT model incorporate affective valence. Interestingly, in a recent study, arousal was a stronger predictor of  
 608 motivation states to move than affective valence (Budnick et al., 2022), and arousal and affective valence did not interact  
 609 to predict ACMS (likely because the study was underpowered). Lastly, the WANT model includes dimensions of A) Move  
 610 versus Rest motivation combined with B) approach and avoidance motivation (Skinner et al., 2009). In other words, there  
 611 is also a drive to “not move”. Addressing both, Bridges (Bridges, 1936) comments, “[The child has] a tendency to  
 612 arrestation of movement upon sudden extensive change or intense sensory impact. Accumulated experience makes of  
 613 this reaction a drive to avoid the obnoxious and whatever threatens personal security”, and “Advantageous rest pauses  
 614 between explorations”.

### 616 **Problems with the concept of drive for movement**

617 There are several serious challenges to the idea that bodily movement and exercise are basic needs resulting in drive  
 618 processes. These have been addressed in other papers (Stults-Kolehmainen et al., 2020a, Stults-Kolehmainen et al., 2021b)  
 619 but are worth extending in this current manuscript. To start, one might believe that movement is simply a *bodily function*,  
 620 just like breathing, urination, or defecation – something organisms do that is devoid of motivation. However, one might  
 621 make the case then that sexual behavior is simply a bodily function. Nonetheless, it is typically included as a drive - as it is  
 622 essential for survival, at least as a species, but also because later in life progeny assist in extended care. In some sense,  
 623 movement may be an even higher, a *superordinate drive* because it is necessary to acquire food, water and to engage in  
 624 sex, etc. (the same case could be made for breathing). A second issue is that the drive to move is conflated with  
 625 psychological drives, such as a) the need for autonomy and independence (e.g., children learning to stand, walk), b) as  
 626 well as the needs for competence and productivity (e.g., attempts to accomplish things), c) the need for social interaction  
 627 (Tomova et al., 2020), and/or d) the need for stimulation and sensation seeking (e.g., a need for thrills) (Wilson et al.,  
 628 2014, Babbitt et al., 1990a, Babbitt et al., 1990b, Watten, 1997, Rhodes and Smith, 2006, Ryan and Deci, 2007). For  
 629 example, conditions of being “cooped up” and “stir crazy” likely combine noticeable increases in the drive to move along  
 630 with concomitant upticks in the drive for social interaction (Tomova et al., 2020). It is not within the scope of this  
 631 manuscript to address this issue, but it could be the case that drives and wants are hierarchical, similar to the hierarchies  
 632 delineated by Maslow (Maslow, 1943, Maslow, 1987, Taormina and Gao, 2013) or Sonstroem & Morgan (Sonstroem and  
 633 Morgan, 1989).

634  
 635  
 636

637 Does a drive to move need to exist?

638 A more significant critique could be stated as, “movement is just the means to the ends.” In other words, movement is  
 639 not reinforced in itself, and people do not move just for the sake of moving. To put it differently, movement is merely  
 640 instrumental or utilitarian. It is true that movement accomplishes many things for us— it is a means to an end. It  
 641 accomplishes, up until the modern age, almost everything needed for sustenance. Through movement, we may acquire  
 642 food, labor to produce goods, propagate, even shake our muscles to become warm (Garland et al., 2011). Moreover,  
 643 movement allows us to not only exploit but also explore our world (Inzlicht et al., 2014, Butler, 1953) and to remove  
 644 obstructions in the process. As Bridges (Bridges, 1936) notes, humans have a “strong utilitarian drive for adaptive  
 645 exploitation” – accomplished by our limbs. Consequently, one might conclude that it requires no reinforcement as well as  
 646 no drive to energize it.

647 Would a [strong] drive to move do more harm than good?

648 As established above, movement is very useful, but it comes at a cost and must be counter-balanced. Humans also strive  
 649 to “avoid undue expenditure of energy,” and “rest allows other interests to come into force and direct behavior” to allow  
 650 “processes of organization and action planning or thought” to take place (Bridges, 1936). If movement was as lucrative as  
 651 food or sleep, we may not stop, which would detract from other needs, mitigate adaptation and possibly be destructive  
 652 to the body. Indeed, this is substantial risk for those with akathisia or exercise addiction/dependence (Lichtenstein and  
 653 Jensen, 2016), and most well-trained athletes know the importance of balancing exercise and rest. Consequently, while  
 654 classic drives have strong signals, like the drive for food (pangs or hunger) or the drive for sleep (tiredness), humans have  
 655 developed relatively weak signals to move (as well as relatively weak signals to *not* sleep - e.g., when awakening).  
 656 Furthermore, movement has been so instrumental and necessary for survival that strong signals to move were  
 657 unnecessary. Up until the modern time, the drives for food, water, etc. (with their signals) were mostly sufficient to initiate  
 658 and maintain necessary movement. Rather, we have strong signals to stop movement (i.e., pain and soreness).  
 659 Nevertheless, the urge to rest is not simply a contra-drive in opposition to movement, but rather works in concert with it  
 660 to maximize adaptation, an idea gaining greater ground (Stults-Kolehmainen et al., 2020a, Stults-Kolehmainen et al.,  
 661 2021b, Stults-Kolehmainen et al., 2022a).

662 Appetite and appetite for movement

663 All of this being said, how do we rectify these issues with the fact that some people, and maybe many people, do move  
 664 just for the sake of moving? Even when it is not necessary to move, people do it anyway. Likewise, people eat, rest, and  
 665 have sex, even when there is no compelling need to do so, and there is no buildup of tension to release. These activities  
 666 may all provide a source of pleasure, and engaging in them is not to just rid oneself of tension. However, it is generally  
 667 agreed that movement and exercise are not highly pleasurable for most people, and aversions associated with movement  
 668 may certainly be a large barrier for movement for some (McBeth et al., 2010). On the other hand, movement may not be  
 669 a large source of aversive sensations either. With the balance of reinforcement at play, it might be concluded that  
 670 movement is generally agreeable (Stults-Kolehmainen et al., 2020a, Garland et al., 2011). One can imagine that people  
 671 have an “appetite” to move (Rowland, 1998), which has been called “appetence” (Ferreira et al., 2006). The drive and  
 672 desire to move does exist, mostly because bodily movement is the vehicle by which we accomplish things, but it is  
 673 regulated relatively without notice, usually only rising into awareness when it becomes disordered (e.g., Restless Legs  
 674 Syndrome) or bothersome (with prolonged deprivation) (Stults-Kolehmainen et al., 2022b) or when a person is specifically  
 675 queried about it (Stults-Kolehmainen et al., 2020b, Stults-Kolehmainen et al., 2021b, Stults-Kolehmainen et al., 2022a).

676 If humans have a basic drive to move, why don't they?

677 This is a particularly vexing issue for some of those who are least active – middle-aged to older adults from WEIRD  
 678 populations (Henrich et al., 2010). One might argue that the need to move is a phenotype heterogeneously distributed  
 679 across the population. I believe that a stronger argument, however, is again from Bridges (Bridges, 1936), who argues that  
 680 drives are developmental and vary across the lifespan. It is obvious that most children have a strong drive to move. Easy  
 681 is it to find a child that enjoys frolicking – engaging in playful movement, which is highly stimulating for growth, maturation  
 682 and socialization (Stults-Kolehmainen et al., 2020a). Movement seems to be a strong drive from birth, peaking around the  
 683 age of maximal physical development. In this regard, as one ages, the urge to move declines as it is less useful to develop  
 684 the body and mind – there is a switch from an emphasis on development to maintenance and slowing down decay. In  
 685  
 686  
 687

short, movement loses its “adaptive value” as one ages. Middle-aged and older people ostensibly experience diminished drive to move, and there is some evidence from a study that followed people for two years that the desire to move decreased with age (Stults-Kolehmainen et al., 2021b). It may also be the case that drive is attenuated through repeated pressure in childhood to remain still and control impulses (Seli et al., 2014). Observations such as these do not lead to a conclusion that there is no drive to move. Consider another basic drive – sex. Like movement - desire for sex varies across the lifetime. Children have apparently no drive for sex, and it ostensibly diminishes with age for most of the population. Simply put, just because children, the infirm and elderly have minimal libido doesn’t mean that sex drive doesn’t exist.

Drives are malleable to time and place - and certainly era as well. As with previous comments above, one should note that rapid technological advancement has changed the dynamics of desire, but not expunged them. As Bridges states (Bridges, 1936), a drive “undergoes processes of development and change of form in response to environmental condition.” Changes may follow several routes. Drives can be counter-conditioned according to Hull’s (Hull, 1943, Hull, 1952) basic formulas. For instance, children usually learn to sit and be still. Drives are also highly responsive to internal and external (i.e., endogenous and exogenous) environmental stimuli (Loewenstein, 1996). The modern, obesogenic world, provides an overload of stimulation, but perhaps a lack of natural environmental stimuli (e.g., light, to which movement was ostensibly paired) (Lake and Townshend, 2006, Wilson et al., 2014). Competing stimuli and drive may overpower (i.e., overtake) or overshadow (e.g., drown out) drive for movement. Alternatively, the need for movement may be satiated by digital movement stimuli provided in rich content from social media memes, short video clips, television, and video games (Rowland, 1998). The average person is also much larger than before (Wong et al., 2022), and this increased size is associated with aversions to movement, such as painful sensations in the joints, skin friction, and other nuisances (Speck et al., 2014, Purim et al., 2015).

## **Future research**

### Negative reinforcement

Rapid progress is being made in theory development for physical activity, exercise and sedentary behaviors. However, the dominant perspective at this juncture is on affect and the reinforcing power of pleasure (Ekkekakis and Zenko, 2016, Williams and Bohlen, 2019, Jones and Zenko, 2021). Emphasis is also placed on punishment (experience of pain) and aversions associated with exercise, typically above ventilatory threshold (Ekkekakis et al., 2005, Ekkekakis et al., 2011). Negative reinforcement is typically considered in terms of reductions in anxiety and depressed mood and the analgesic effect of exercise (for some people in some situations) (Bartholomew et al., 1996, Busch et al., 2016, Bartholomew et al., 2005). Rarely are the various sources of displeasure comprehensively included, however (Backhouse et al., 2007). In short, most models of physical activity motivation do not include basic drive, which may be a source of considerable displeasure, arousal, and tension for many people, particularly those who are healthy and younger, but also for those suffering from a wide range of conditions (Stults-Kolehmainen et al., 2022b). Future developments should consider all of these factors (see Table 2).

### Appetitive versus reflective desires

Future research should consider interactions between: 1) appetitive (e.g., hedonic-oriented) and reflective (e.g., cognitive) sources of desire (Williams and Bohlen, 2019), 2) need states versus appetite, 3) primary versus secondary drives/wants and, 4) the various primary drives. For instance, when satiated with food, individuals report lower desire to move (Budnick et al., 2022), which may be related to processes of digestion. Basic drive, however, is not dependent on appetite or reflection and is highly automatic; thus, it should be considered within the domain of automaticity and Type 1 behavioral processes (Brand and Ekkekakis, 2018). Lastly, could subjective feelings of drive to move be misattributed to other sources of tension? Feelings of being antsy (due to a lack of movement) could be attributed to external sources of stress, such as work anxiety.

### Measurement

Measuring drive continues to be a challenge and varies with one’s definition of it (see above). The behavioral manifestations (e.g., locomotion) may be measured by direct observation (Galton, 1885) or with subjective (Seli et al., 2014) and objective measures of fidgeting, such as Nintendo Wii Balance boards (Seli et al., 2014). Tension, the result of deprivation (i.e., of movement) may be detected indirectly through tools that have been developed to measure affective

valence (e.g., Feeling Scale) and arousal (e.g., Felt Arousal Scale). The transient want or need of movement (i.e., the subjectively felt motivation state) may also be measured with the CRAVE and ARGE scales, which have 13-item and 2-item versions (Stults-Kolehmainen et al., 2021b, Filgueiras et al., 2022). There is no known instrument to measure associated feelings (e.g., fidgetiness, restlessness, antsiness) and motor changes, such as trembling, shaking, raking of the limbs, etc. (Tiidus, 2008). Direct observation in the laboratory is sorely needed to witness and document these phenomena.

#### Mechanisms

These data should be combined with biomarkers likely associated with drive for activity, including orexin (i.e., hypocretin), leptin, testosterone, cortisol, dopamine, activity in the nucleus accumbens, ventral tegmental area and substantia nigra, vagal drive/HRV/RSA, genetics and the microbiome (Garland et al., 2011, Dohnalová et al., 2022, España et al., 2002, Scheurink et al., 2010, Casper, 2022, Willerman, 1973, Aoyagi et al., 2003, Salamone and Correa, 2002, Furlong et al., 2009). There is likely huge inter-individual variability in drive, which may be related to stress coping style, temperament, impulse control, personality, and other factors (Rhodes and Smith, 2006, Garland et al., 2011, Seli et al., 2014). Drive for specific types of movement, such as moving in short spurts, or for extended periods of time (Belke and Garland, 2007), may be associated with properties of muscle and may be conditioned as well.

#### **Application**

##### To research methods

The concept of drive might have general application for experimentation and data interpretation in exercise science. Frequently, study participants are asked to refrain from exercise before assessments and training protocols (SantaBarbara et al., 2020, Aoyagi et al., 2003) and/or to take time off from their normal routines (Stults-Kolehmainen and Bartholomew, 2012, Stults-Kolehmainen et al., 2014, Stults-Kolehmainen et al., 2016). This is ostensibly to ensure that participants have adequate energy, no muscle damage, and any effect of previous training is “washed out”, particularly in within-subjects, randomized cross-over trials (Ballmann et al., 2021). However, it should also be considered that depriving movement for individuals accustomed to physical activity results in increased drive or motivation state, perhaps with noticeable increases in arousal, desire to move, and alterations to locomotion (e.g., increased fidgeting, pacing). Therefore, researchers should be mindful of this effect, and ideally, attempt to monitor it as it may influence psychomotor measures. The current author recounts a presentation at a prestigious medical school involving so-called “exercise” in rodents, where a psychiatric researcher presented a protocol that involved depriving rats of their running wheels for several days - and then permitting them access to wheels to observe the effects of exercise. It may be more accurate to assert that such a protocol is a test of *depriving movement* as opposed to providing exercise, or perhaps both (Garland et al., 2011, Rhodes et al., 2003, Malisch et al., 2009). Such pitfalls could probably be avoided with careful design of experiments and appropriate timing of procedures.

##### To clinical practice

To reiterate, movement is a basic need and a primary drive, and loss of it may result in rapid decline of health. This is relevant for most of healthcare, but particularly true for surgery, where patients face extended time on the operating table (2+ hours) and days of bed rest. Various machines (e.g., “compression boots”) are useful to prevent some of the ill effects of inactivity (e.g., blood clots) (Keith et al., 1992). Enhanced recovery protocols (e.g., ERAS) require early ambulation at regular intervals (Pędziwiatr et al., 2018). Patients who engage in this movement gain faster recovery, less pressure ulcers, shorter hospital stays, and fewer complications (Adogwa et al., 2017). There is also potential for pain analgesia and less agitation. In short, exercise is medicine (Pedersen and Saltin, 2015), and movement must be prescribed the same as the dietary regimen, pain relief, and breathing/spirometry exercises.

##### To primary education

Children are most susceptible to the effects of drive, and potentially have the most to gain from movement. Classrooms should be designed to allow for greater movement, and lessons should incorporate physical activity, within reason (Bartholomew and Jowers, 2011). Sometimes small changes to lesson planning (e.g., writing, then reading) can help children to dissipate drive, while also enhancing learning (Elbow, 2004). The benefits of regular playtime and recess from studies are substantial (Ramstetter et al., 2010).



**CONCLUSION**

The concept of drive, or motivational energy, as a precipitator of human behavior is an old but re-emerging idea - providing a unique and rarely-considered perspective on physical activity engagement. Drive is the impetus to attain needs and thus restore homeostasis - returning to optimal conditions of functioning. Drive states have certain properties, as demonstrated above, such as the experience of deprivation, then tension, consumption, relief and satiation. They are under a large degree of homeostatic control but are also responsive to environmental stimuli and conditioning and include dimensions of approach and avoidance. More practically, it may be operationalized as a motivation state, characterized by negative affect, arousal, and a desire to acquire a need. Older theories of behavior highlighting drive, such as Drive Reduction Theory, have been largely sidelined in favor of higher performing models. Regardless, one may argue that movement is a primary need for most humans, most notably in younger years, but perhaps continuing well into older age. Biological processes evolved in physical bodies that moved, making these functions optimized under such conditions. As such, the need for movement can provide a significant source of tension, the relief of which is negative reinforcement – potentially strengthening the physical activity response. This tension may be measured with the CRAVE and ARGE scales, new instruments developed to evaluate desires, wants, urges, and cravings for physical activity (Stults-Kolehmainen et al., 2021b, Filgueiras et al., 2022). Conditions of being constrained or otherwise deprived of movement may result in alternations in motivation states, along with stoked feelings of being antsy, fidgety, and restless, along with concomitant changes in non-exercise activity thermogenesis (NEAT). However, comprehensive studies have yet to be earnestly conducted in humans. Nevertheless, this conceptualization may be useful for generating new models of behavior, such as the WANT model, which will boost our understanding of movement behaviors, including physical activity and exercise.

**AUTHOR CONTRIBUTIONS**

MSK is responsible for all aspects of the scholarly work.

**FUNDING**

The author reports no sources of funding.

**ACKNOWLEDGEMENTS**

Thanks to Brandon Alderman, PhD (Rutgers University, New Brunswick, NJ), Sunao Akashi Slayton, PharmD BCOP (Smilow Cancer Hospital, Yale New Haven Hospital, New Haven CT), Riley Avila, BS (Teachers College – Columbia University, New York, NY), Jessica L. Barker, MS (University of Minnesota, St. Paul, MN), Amanda Divin, PhD (Texas A&M University, Commerce, TX), Paul McKee, BS (Duke University, Raleigh, NC), Fabio Amador Bueno (Connecticut State Community College Nursing Program, New Haven, CT), Michael Busa (University of Massachusetts, Amherst, MA), Rebecca Koenigsberg, LCSW (Yale New Haven Hospital, New Haven, CT), Philip R. Stanforth (The University of Texas, Austin, TX), and John B. Bartholomew, PhD (The University of Texas, Austin, TX) for insights and technical assistance making this work possible. The leadership of Yale New Haven Hospital (Division of Digestive Health, New Haven, CT) is also greatly appreciated, including Rebecca Lamberti, DNP, and Bethany Mulone, MSHA.

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Table 1. Some classic, primary (i.e., “genuine”) drives, including bodily movement and physical activity

	<b>Need</b>	<b>Behavior (voluntary)</b>	<b>Associated bodily functions (many involuntary)</b>	<b>Need state of deprivation (negative tension)</b>	<b>Descriptor</b>	<b>Physical manifestations and symptoms*</b>	<b>Psychological desire (positive tension)</b>	<b>Satiation state / descriptor</b>
1	Food	Ingestion, eating	Digestion, absorption, defecation	Hunger	Hungry, peckish	Stomach growls and tightens	Appetite	Full, fullness
2	Water	Ingestion, drinking	Hydration, urination	Thirst	Thirsty, parched	Dry mouth and throat, headache		Quenched
3	Sleep	Sleeping	Rest, convalescence	Somnolence, fatigue	Sleepy, tired	Drooping, slouching		
4	Sex	Copulation	Sexual arousal / receptivity, erection, orgasm	Sexual frustration	Concupiscent, aroused	Genital arousal, pacing and distracted movements, nocturnal emissions	Libido, arousal	
5	Movement	Physical activity (PA), Ambulation, exercise, moving	Non-exercise activity thermogenesis (NEAT); spontaneous PA	Restlessness	Restless, antsy, fidgety	Shaking muscles, stretching limbs, sweating, pacing, fidgeting, tapping	Appetence, activation	Exertiated †

\* There are generalized physical symptoms common to many/most needs (e.g., restlessness) as well as specific and localized ones.

† Portmanteau of “exert” / “exercise” and “satiated”. Exertiated is a stopping state, whereas “exerting” would be a starting or continuing state. “Exertiate” is the verb. In creating this term, we also considered “acti-fied”, the portmanteau of “active” and “satisfied”, but this may be confused with the word “actify”, which sometimes means “to start, activate or put into action”.

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Table 2. Examples of sensations of tension that may result in physical movement

		Source of stimulus*	
		Internal (Innate / Endogenous)	External (Exogenous)
Valence of stimulus	Negative	Drive, Pain, depressed mood	Work stress, social anxiety
	Positive	Runner's high	Groove†

\* See Seward & Seward (Seward and Seward, 1937)  
 †Sensation of wanting to move in response to music